

[001] MULTI-STEP TRANSMISSION

[002]

[003]

[004] The present invention relates to a multi-step transmission in planetary style, in particular an automatic transmission for a motor vehicle in accordance with the preamble of patent claim 1.

[005]

[006] In accordance with the state of the art, automatic transmissions intended especially for motor vehicles comprise planetary gear sets that are shifted by means of friction or switch elements, such as couplings and brakes, and are usually connected to a starter element, which is subjected to a slip effect and selectively to a starter element equipped with a bypass clutch, such as a hydrodynamic torque converter or a hydraulic coupling.

[007] A transmission such as this can be seen in EP 0 434 525 A1. It comprises essentially an input shaft and an output shaft, which are arranged parallel to each other, a double planetary gear set arranged concentric with respect to the output shaft and five switch elements in the form of three clutches and two brakes, whose selective locking, respectively in pairs, determines the different gear ratios between the input shaft and the output shaft. For this purpose, the transmission has a front-mounted gear set and two power paths so that six forward gears are obtained by way of the selective meshing in pairs of the five switch elements.

[008] In the first power path, two clutches for transmitting the torque from the front-mounted gear set to two elements of the double planetary gear set are required. These are arranged in the direction of the power flow essentially behind the front-mounted gear set in the direction of the double planetary gear set. In the second power path, another clutch is provided, which detachably connects the same to a further element of the double planetary gear set. The clutches are arranged herein such that the inner disk support forms the output.

[009] A compact multi-step transmission in planetary style, intended especially for a motor vehicle, is also known from United States patent 6,139,463, which has two

planetary gear sets and one front-mounted gear set as well as three clutches and two brakes. Two clutches C-1 and C-3 are provided in a first power path in order to transmit the torque from the front-mounted gear set to the two planetary gear sets in this known multi-step transmission. The outer disk support or the cylinder or piston and pressure equalization side of the clutch C-3 is herein connected to a first brake B-1. In addition, the inner disk support of the third clutch C-3 is connected to the cylinder or piston and pressure equalization side of the first clutch C-1, wherein the inner disk support of the first clutch C-1 is arranged on the side of the output and is connected to a sun gear of the third planetary gear set.

[010] In addition, a multi-step transmission is known from DE 199 49 507 A1 of the Applicant, in which two forward-mounted gear sets, which are not shiftable, are provided on the input shaft and these gear sets generate two speeds on the side of the output which, aside from the speed of the input shaft, can be optionally shifted on a shiftable double planetary gear set that acts on the output shaft in such a way by means of optionally locking the employed switch elements that in order to shift from one gear into the respective next higher or lower gear only one of the two switch elements that were just actuated must be activated or deactivated.

[011] An automatically shiftable motor vehicle transmission having three spider supported planetary sets as well as three brakes and two clutches in order to shift six forward gears and one reverse gear and having an input shaft as well as an output shaft is known furthermore from DE 199 12 480 A1. The automatically shiftable motor vehicle transmission is configured in such a way that the input shaft is connected directly to the sun gear of the second planetary gear train, and that the input shaft can be connected via the first clutch to the sun gear of the first planetary gear set and/or via the second clutch to the planet carrier of the first planetary gear set. In addition or as an alternative thereto, the sun gear of the first planetary gear train can be connected via the first brake to the housing of the transmission and/or the planet carrier of the first planetary gear set can be connected via the second brake to the housing and/or the sun gear of the third planetary gear set can be connected via the third brake to the housing.

[012] It is the object of the present invention to propose a multi-step transmission of the kind mentioned above, in which the constructive effort is optimized and, in addition, the effectiveness in the main driving gears is improved with respect to drag loss and gearing loss. In addition, low torque should act on the switch elements and planetary gear sets and also the speeds of the shafts, switch elements and planetary gear sets should be kept as low as possible in the multi-step transmission of the invention. In addition, the number of gears as well as the transmission spread should be increased.

[013] This object is attained in accordance with the invention by means of the features of patent claim 1. Further advantages and advantageous embodiments can be inferred from the dependent claims.

[014]

[015] A multi-step transmission in planetary style having an input shaft and an output shaft, which are arranged in a housing, is proposed in accordance with the invention. In addition, at least three spider supported planetary gear sets, at least seven rotatable shafts, as well as six switch elements comprising brakes and clutches are provided, whose selective meshing effects different gear ratios between the input shaft and the output shaft so that preferably seven forward gears and one reverse gear can be realized.

[016] According to the invention, it is provided in the multi-step transmission that the input occurs by means of a shaft, which is in permanent connection with an element of the first planetary gear set and the output occurs via a shaft, which is connected to the planet carrier of the second planetary gear set and to the planet carrier of the third planetary gear set. Furthermore, it is provided in the multi-step transmission, according to the invention, that a further shaft is in permanent connection with another element of the first planetary gear set; another shaft is in permanent connection with the ring gear of the second planetary gear set and the ring gear of the third planetary gear set; another shaft is in permanent connection with the sun gear of the third planetary gear set, another shaft is in permanent connection with the ring gear of the first planetary gear set, and another shaft is

in permanent connection with the sun gear of the second planetary gear set, while the planetary gear sets are coupled to shafts and switch elements. The input shaft can herewith be connected to the sun gear or to the planet carrier of the first planetary gear set, while the one other shaft that is connected to the first planetary gear set is accordingly connected to its planet carrier or sun gear.

[017]        The first and third planetary gear sets are configured as plus planetary gear sets; the second planetary gear set is a minus planetary gear set.

[018]        The embodiment of the multi-step transmission results in suitable gear ratios as well as a considerable increase of the total spread of the multi-step transmission, leading to an improvement in the driving comfort and a significant reduction in fuel consumption.

[019]        The multi-step transmission is suitable for any motor vehicle, in particular for automobiles and utility vehicles, such as trucks, buses, construction equipment, rail vehicles, crawler chain vehicles and the like.

[020]        The construction effort is considerably reduced with the multi-step transmission of the invention by means of a low number of switch elements, preferably four clutches and two brakes. The multi-step transmission of the invention beneficially offers the possibility of carrying out a startup with a hydrodynamic converter, an external starting clutch or also with other suitable external startup elements. It is also conceivable to enable a starting operation with a starting element integrated into the transmission. A switch element that is actuated in the first gear and in the reverse gear is preferred.

[021]        Good efficiency in the main driving gears in terms of drag and gearing losses can further result from the multi-step transmission according to the invention.

[022]        Additionally, low torque exists in the switch elements and in the planetary gear sets of the multi-step transmission, whereby wear can be considerably reduced in an advantageous way in the multi-step transmission. The low torque enables also accordingly small dimensions, whereby the required installation space and the corresponding costs are reduced. Moreover also low speeds exist on the shafts, the switch elements and the planetary gear sets.

[023] The transmission of the invention is also designed such that adaptability to different drive train embodiments is made possible in the direction of power flow as well as also from a space point of view.

[024]

[025] The invention will be described in more detail in the following with reference to the drawings, wherein:

[026] Fig. 1 shows a schematic view of a preferred embodiment of a multi-step transmission according to the invention;

[027] Fig. 2 shows a schematic view of a further preferred embodiment of a multi-step transmission according to the invention; and

[028] Fig. 3 shows a circuit diagram of the multi-step transmission according to the invention shown in Figs. 1 and 2.

[029]

[030] The multi-step transmission is depicted in Figs. 1 and 2 with an input shaft 1 (An) and an output shaft 2 (Ab), which are arranged in a housing G. Three spider supported planetary gear sets P1, P2, P3 are provided. The first planetary gear set P1 and the third planetary gear set P3 are configured herein as plus planetary gear sets; the second planetary gear set P2 is configured as a minus planetary gear set in accordance with the invention.

[031] It is also possible to combine the second planetary gear set P2 and the third planetary gear set P3 as a Ravigneaux planetary gear set with common planet carrier and common ring gear.

[032] As can be seen from Figs. 1 and 2, merely six switch elements, namely, three brakes 03, 04, 05 as well as three clutches 14, 56 and 67 are provided.

[033] Selective shifting of seven forward gears and one reverse gear can be realized with the switching elements. The multi-step transmission has a total of seven rotatable shafts according to Fig. 1, namely, the shafts 1, 2, 3, 4, 5, 6 and 7.

[034] According to the invention, it is provided in the multi-step transmission of Fig. 1 that the input occurs by means of the shaft 1, which is in permanent connection with the planet carrier of the first planetary gear set P1. The output occurs via the shaft 2, which is connected to the planet carrier of the second planetary gear set P2 and the planet carrier of the third planetary gear set P3. The shaft 3 is in permanent connection with the sun gear of the first planetary gear set P1 and the shaft 4 is in permanent connection with the ring gear of the second planetary gear set P2 and the ring gear of the third planetary gear set P3. The shaft 5 is furthermore in permanent connection with the sun gear of the third planetary gear set P3. The further rotatable shaft 6 is in permanent connection with the ring gear of the first planetary gear set P1, wherein the shaft 7 is in permanent connection with the sun gear of the second planetary gear set P2.

[035] In the multi-step transmission according to the invention, the shaft 3 can be coupled by means of the brake 03; the shaft 4 can be coupled by means of the brake 04 and the shaft 5 can be coupled by means of the brake 05 to the housing G. The clutch 14 connects the shaft 1 and the shaft 4 detachably to each other; the shaft 5 and the shaft 6 can be detachably connected by means of the clutch 56. The clutch 67 also detachably connects the shafts 6 and 7.

[036] Fig. 2 shows a further embodiment of the multi-step transmission according to the invention. The only difference compared to the embodiment of Fig. 1 consists in that the drive shaft 1 is connected to the sun gear of the first planetary gear set P1 and that the shaft 3 is in permanent connection with the planet carrier of the first planetary gear set P1.

[037] Fig. 3 depicts a circuit diagram of the multi-step transmission according to the invention, in accordance with Figs. 1 and 2. A respective gear ratios  $i$  of the individual gear levels and a level jumps  $\varphi$  to be determined therefrom can be seen, for example, from the circuit diagram. It can also be seen from the circuit diagram that double shifting can be prevented in the case of sequential shifting, since two neighboring gear levels jointly utilize two switch elements, respectively.

[038] The brake 03 is permanently activated for the first four gears; in addition, the brake 04 and the clutch 67 are engaged for the first gear; the brake 05 and the

clutch 67 are engaged for the second gear; the clutches 56 and 67 are engaged for the third gear and the clutches 14 and 67 are engaged for the fourth gear. The clutches 14, 56 and 67 are engaged for the fifth gear. The sixth gear results from engaging the brake 03 as well as the clutches 14 and 56 in accordance with Fig. 3; the seventh gear requires the clutch 14 as well as the brakes 03 and 5. For the reverse gear the brakes 03 and 04 as well as the clutch 56 are engaged.

[039] It is possible, according to the invention, to provide additional free wheels at each suitable location of the multi-step transmission, for example, between a shaft and the housing or possibly to connect two shafts.

[040] It is also possible by means of the design to arrange the input shaft and output shaft, preferably for transverse wheel drive, front wheel drive, longitudinal wheel drive, rear longitudinal wheel drive or all wheel drive arrangements on the same side of the transmission or the housing. On the side of the input shaft or on the side of the output shaft, in addition, an axle differential and/or a inter-axle differential can be arranged.

[041] Within the scope of an advantageous further development, the input shaft 1 can be separated according to need by means of a coupling element from a driving motor, wherein a hydraulic clutch, a hydrodynamic converter, a hydraulic coupling, a dry starting clutch, a wet starting clutch, a magnetic powder clutch or a centrifugal clutch can be used as coupling element. It is also possible to arrange such a starting element behind the transmission in the direction of power flow so that, in this case, the input shaft 1 is in permanent connection with the crankshaft of the engine. Starting can occur also by means of a switch element of the transmission. The brake 04, which is activated in the first forward gear as well as also in the first reverse gear, is preferably used as the starting element.

[042] The multi-step transmission, according to the invention, also enables the arrangement of a torsional vibration damper between the engine and the transmission.

[043] Within the scope of another embodiment, which is not depicted, a wear-free brake, such as a hydraulic or electric retarder or the like, can be arranged on each shaft, preferably on the input shaft 1 or on the output shaft 2, which is of particular

importance in particular for use in utility vehicles. An auxiliary drive can be provided in addition, preferably on the input shaft 1 or the output shaft 2, in order to drive the additional units on each shaft.

[044] The used switch elements can be configured as power-shifting clutches or brakes. Non-positive clutches or brakes, such as multi-plate clutches, band brakes, and/or cone couplings, in particular, can be utilized. As switch elements also positive locking brakes and/or clutches, such as synchronizations or dog-type clutches can be used.

[045] A further advantage of the multi-step transmission presented herein consists in that an electric machine can be accommodated on each shaft as generator and/or as additional driving machine.

[046] The functional features of the claims can be configured in the most different way in their design. For reasons of simplicity, these possible design embodiments are not explicitly described. However, each design configuration of the invention is covered by the protected scope of the claims, in particular any spatial arrangement of the planetary gear sets and the switch elements as well as with respect to each other and insofar as they are technically practical.



Reference Numerals

1	shaft
2	shaft
3	shaft
4	shaft
5	shaft
6	shaft
7	shaft
03	brake
04	brake
05	brake
14	clutch
56	clutch
67	clutch
P1	planetary gear set
P2	planetary gear set
P3	planetary gear set
An	input
Ab	output
i	gearing
$\phi$	level jump
G	housing